RESEARCH BULLETIN 796 NOVEMBER 1957

Surface Mulches and Mulch Tillage for Corn Production

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Wooster, Ohio
and
AGRICULTURAL RESEARCH SERVICE, U.S.D.A.
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CONTENTS

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ACKNOWLEDGMENTS

Acknowledgment is due Dr. R. E. Yoder who initiated the preliminary work in 1946 and to Dr. C. E. Evans who revised it in 1949.

SURFACE MULCHES AND MULCH TILLAGE FOR CORN PRODUCTION

H. L. BORST[1] and H. J. MEDERSKI[2]

INTRODUCTION

The erosion hazard in growing corn and other row crops on sloping land is well recognized. Valuable rainfall is lost and the soil erodes seriously when the churning action of rain falling on unprotected soil beats the surface into a structureless mass which seals it and prevents the intake of rainfall. This destructive action by rainfall is prevented by dense vegetation or crop residues on the soil which absorb the energy of falling rain and thus decrease erosion at its source.

In the present work two methods of protecting the soil surface in corn fields were studied to determine their effect on corn yields. The methods were (a) application of mulches of strawy manure or straw alone after the crop was planted and (b) mulch tillage. The latter is a method of soil preparation which loosens the soil and destroys existing vegetation but unlike plowing, leaves the residue from the previous crop on and in the surface rather than buried under the furrow slice.

The chief objective of this study was to determine the effect of surface mulches and mulch tillage on corn yield and physical characteristics of the rootbeds. A separate experiment was also carried to determine the erosion and water-control value of mulches.

LITERATURE

Numerous studies have shown the effectiveness of surface mulches in promoting infiltration and reducing erosion. (1, 3, 4, 5, 13, 15).

Although fruit growers have used surface applied mulches extensively, only a few studies of the effect of this practice on yield of field crops have been reported. Willard et al. (24) in Ohio report that during a 14-year period average corn production was not increased by a 2-ton mulch of straw applied after the first cultivation on nearly level Celina silt loam. Van Doren et al. (23) reported that a mulch of 2 tons of straw per acre reduced corn yields.

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The results of experiments comparing "mulch tillage" with conventional plowing as methods of seedbed preparation for corn in the humid areas of the United States are not consistent and generalization is not warranted. The lack of agreement between the various experiments and the various explanations for the experimental results are not surprising in view of the numerous differences in experimental conditions. The kind of tillage implement used, the thoroughness of tillage, the depth of tillage, the nature of the crop residues and soil and climatic conditions have varied widely.

Jacks et al. (18)[3] have prepared an extensive review of the literature on mulching and stubble mulching and only pertinent references are presented here. Investigators in Iowa and Illinois (8, 9, 23) report reduced yields of corn with mulch tillage systems in which soils were prepared with disks and sweeps. The yield reductions were largest on fine textured soils of low fertility and poor physical condition. One explanation given for these results was restricted mineral absorption due to an inadequate soil oxygen supply (19, 20). In Indiana Baugh et al. (2) found that on coarse textured soil types plowing or deep disking produced larger corn yields than subsurface tillage; on fine textured soils plowing produced significantly larger yields than subsurface tillage or disking. This superiority of plowing to other methods of seedbed preparation was also observed by Free (16) in New York, and Lillard et al. (21) in Virginia. In general, the practice of mulch tillage appears to be better adapted to coarse textured soils than to fine textured poorly drained soils.

Several workers (7, 17, 23) have reported on the erosion-control value of mulch tillage. Of interest are the results from the watersheds of the Hydrologic Experiment Station (17) at Coshocton, Ohio. During a 9-year period mulch tillage of corn land reduced May to October runoff from over 2 inches to less than one-tenth inch. Erosion was reduced from 10 tons per acre to less than one-third ton at the same time.

EXPERIMENTAL PROCEDURE

Three years of preliminary experimentation with a one way disk, TNT plow, Scotch moldboard plow, subtiller with sweeps, and a field cultivator indicated that the desired loosening of the plow layer with minimum coverage of surface residues was most nearly achieved with the field cultivator. On the basis of these comparisons, the field cultivator was used in these mulch tillage investigations.

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[3]Numbers in parentheses refer to literature cited.

The experiments discussed in this paper were located on a gray brown podzolic Canfield silt loam with a 2 to 3 percent slope and with fair internal drainage. The entire experimental area is systematically drained with tile spaced 45 feet apart. The plow layer of this soil contained 18 percent sand, 66 percent silt, and 16 percent clay. Corn, grown in a four-year rotation, was followed by wheat and two years of a good quality timothy-alfalfa sod. The individual plots were 54 feet long and contained six corn rows spaced 42 inches apart with the center four rows harvested for yield.

Four basic treatments, conventional culture, manure mulching, straw mulching and mulch tillage were compared in a single experiment each year from 1949 through 1955. In 1954 a fifth treatment consisting of mulch tillage with a double depth fertilizer placement was added to the basic treatments. In 1955 a sixth treatment consisting of conventional culture with double depth fertilizer placement was added to the five treatments used in 1954. Each year the experiment was designed as a complete randomized block with six replications.

The following is a description of the experimental treatments:

A. Conventional culture—

Manure was spread on the meadow sod at 8 to 10 tons per acre in late spring, plowed under with a moldboard plow, and the seedbed prepared with a disc and harrow. This is conventional practice in Ohio except less manure is usually applied.

B. Manure mulch—

No manure was spread before plowing. Instead, the 8- to 10-ton rate of manure used in treatment A was applied as a mulch to the growing crop at "layby" after the second cultivation. The manure contained considerable straw and was applied with a manure spreader.

C. Straw mulch—

Wheat straw was substituted for the manure used in treatment B and applied by hand as a mulch at 2 tons per acre at layby time after the second cultivation.

D. Mulch tillage—

Manure was applied to the meadow sod. The sod was then disked and worked up with a field cultivator.

E. Mulch tillage as in treatment D, one-half of row fertilizer placed at conventional planter depth, one-half at 5-inch depth. (1954, 1955 only.)

F. Conventional culture, fertilized as in treatment E. (1955 only).

During the first two years of the experiment an ordinary light weight field cultivator was used to prepare the mulch-tilled plots. In the subsequent years the plots were first disked twice at weekly intervals to kill the sod, and then finally prepared with a heavy type field cultivator, Figure 2. The seedbed was finished by disking to smooth the surface. In 1954 the field cultivator was equipped with 8-inch half sweeps and in 1955 shovels resembling small moldboards were used. All tillage operations were carried out parallel to the length of the plots.

From 1949 through 1952, 200 pounds of ammonium nitrate and 150 pounds of muriate of potash per acre were plowed down for corn and 300 pounds per acre of 0-20-20 applied in the row at planting. Wheat received 300 pounds of 0-12-12 per acre applied at planting. After 1952 neither nitrogen nor potassium was applied before plowing

Fig. 1.—Manure mulch applied at 8-10 tons per acre

for corn, instead, the corn was row-fertilizer at planting with 400 pounds per acre of 3-12-12 and the meadows were more heavily fertilized as a substitution for the previously used plow-down application. In 1954 a mulch-tillage treatment was included in which the row fertilizer was divided between two placements, i. e., conventional planter depth and 5 inches deep. In 1955 this double-depth fertilizer treatment was also used in combination with an additional conventional plowing treatment.

During the first 3 years of the experiment the main plots were split to provide a comparison of weed control by conventional cultivation and cultivation plus a 2,4-D weed spray. The purpose of these sub treatments was to evaluate the effect of weed competition on the plowed and mulch tilled plots.

A separate experiment was started in 1951 and continued through 1953 to study the effect of applying manure mulch at different times during the growing season. In 1954 and 1955 the time of mulching

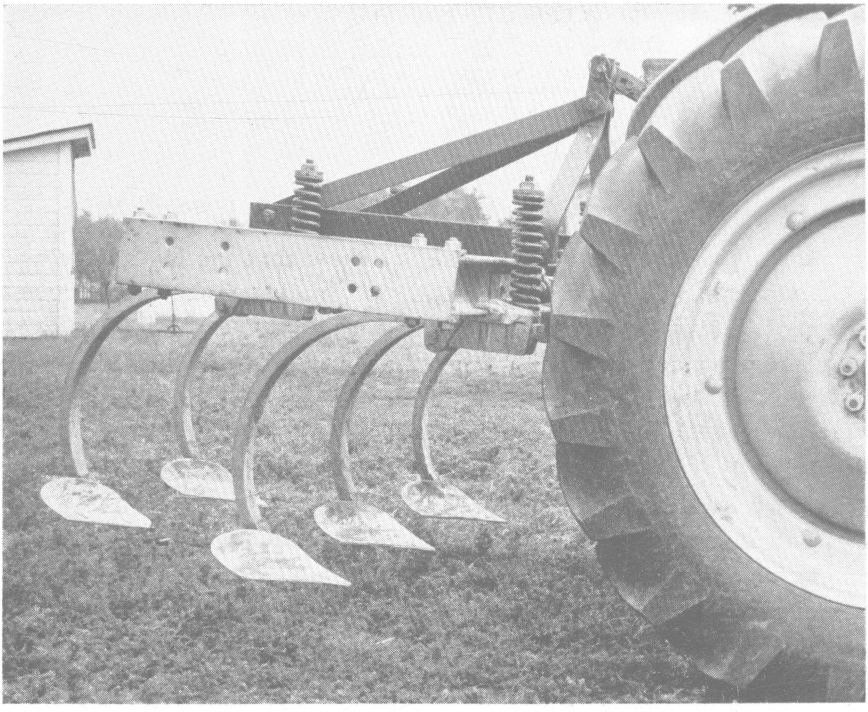

Fig. 2.—Heavy field cultivator equipped with "moldboard" shovels

comparison was included in the main experiment. A comparison was made between (a) applying manure as early as feasible after planting and controlling weeds by spraying with 2,4-D and cultivating once at layby time and (b) cultivating twice and applying the mulch after the last cultivation. The methods and materials used for this experiment were identical with the main experiment except that the slope of the site was 8 percent.

Organic matter and soil water were determined on a composite of six subsamples taken from the 0-6 inch soil layer of the plowed, mulch tilled and surface mulched plots. Soil samples for bulk-density estimates were obtained by use of 3″ × 3″ brass cylinders or by means of a Lutz (22) sampler. Soil temperatures were determined weekly in 1955 with Weston thermometers placed at a depth of 4″ in the corn rows. Soil nitrogen was determined by the Kjeldahl method. Potassium determinations were made on a composite of 25 ear leaf samples. Studies of the soil and water conserving values of surface applied manure mulches were carried out during 1945 at the former S.C.S. experiment station at Zanesville, Ohio, and from 1950 through 1953 at Wooster, Ohio. The method used in this study were those of similar runoff studies (3).

RESULTS

STUDIES OF CORN YIELD, PLANT AND SOIL CONDITIONS

Corn yields. The data in Table 1 show that the 7-year average yield of corn produced on manure and straw-mulched plots was approximately five bushels larger than the yield produced on plowed but non-mulched plots and approximately nine bushels larger than the yield produced on mulch-tilled soil. The yield increase on manure and straw-mulched plots was statistically significant at the 5 percent level. Similar increases in corn yield from the application of a manure mulch are shown in Table 2 for 1951, 1952 and 1953. Thus, in eight out of ten comparisons the yield of corn was larger when the manure was applied as a surface mulch than when it was plowed down. Early and late application of the manure mulch appeared to be equally effective (Table 2). The difference between yields produced by plowing under the manure and the application of manure or straw mulch after plowing was greater during the period from 1951 through 1954 when the May through August rainfall was less than 15 inches.

TABLE 1.—Yield of Corn as Affected by Mulch Tillage and Surface Applied Mulches

Treatment	1949	1950	1951	1952	1953	1954	1955	7-year Av.	Av. of 4 dry years 1951-'54
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
A. Manure plowed under	119.3	102.0	92.1	108.6	82.4	82.8	107.2	99.2	91.5
B. Manure mulch	119.3	100.3	103.2	119.2	90.0	84.6	111.6	104.0	99.3
C. Straw mulch	108.2	101.8	102.7	119.9	96.6	89.1	113.1	104.5	102.1
D. Mulch tillage	107.9	101.7	93.7	107.0	76.6	80.7	100.4	95.5	89.6
E. Mulch tillage*	. . .	. .	. . . .	. . . .	. . . .	85.6	106.1	. . . .	. . . .
F. Manure plowed under*	. . .	. .	. . . .	. . . .	. . .	.	107.4	. . .	. . . .
L.S.D. (.05)	6.0	N.S.	9.4	8.7	5.3	4.0	N.S.	5.1	4.4
L.S.D. (.01)	8.3	N.S.	N.S.	12.2	7.3	5.4	N.S.	7.0	6.2
Inches rainfall (May-August)	15.2	18.3	13.2	11.6	11.4	6 9	14.4	. . . .	. . . .

*Row fertilizer at conventional planter depth and at 5-inch depth.

TABLE 2.—Yield of Corn as Affected by Time of Applying Manure as Surface Mulch

Treatment	1951	1952	1953	1954	1955	Average
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Manure plowed down	98.5	95.7	66.2	82.8	107.2	90.1
Manure mulch applied early. Cultivated at layby time . . .	107.3	108.1	68.9	87.9	108.5	96.1
Cultivated. Manure mulch applied late at layby time	99.9	105.3	71.5	84.6	111.6	94.0
Manure mulch early. No cultivation	95.1	....	64.7	...	....	....
L.S.D. (.05)	N.S.	5.6	N.S.	4.0	N.S.	3.8
(.01)	N.S.	8.1	N.S.	N.S.	N.S.	5.4

The data in Table 1 also show that the 7-year average yield of corn on mulch-tilled plots was less than the yields produced by plowing under the manure. Although the yield difference was not statistically significant, larger yields were produced on the plowed plots in five out of seven years. This yield disadvantage of mulch tillage appeared to be eliminated by deep fertilizer application. The difference in yield between conventional and deep fertilizer placement on the mulch-tilled plots was statistically significant in 1955. In general, mulch tillage produced the lowest corn yield while the application of mulches after plowing produced the highest corn yields.

TABLE 3.—Potassium in Corn Plants on Plowed and Mulch Tilled Soil

	1954		1955	
	July 7	August 11	July 25	Average
	%	%	%	%
Plowed	2.05	1.54	2.26	1.95
Mulch tilled*	1.89	1.39	2.27	1.85
Mulch tilled†	1.99	1.51	2.28	1.92
L.S.D. (.05)	.105	.114	N. S.	
(.01)	.146	N. S.		

*Conventional row fertilization.

†One-half fertilizer conventional, one-half at 5 inches depth.

TABLE 4.—Percent Soil Moisture in the 0-6 Inch Depth as Affected by Mulch Tillage and Surface Applied Mulches

Treatment	1949	1951		1953		1954		1955	
	Aug.	July	Aug.	Aug.	Sept.	July	Aug.	June	Aug.
Plowed, manure under	17.1	21.1	14.2	10.0	6.7	8.3	10.0	16.4	10.2
Plowed, manure mulch	19.6	....	. .	13.5	7.4	8.3	10.4	....	19.2
Plowed, straw mulch	....	....	...	14.3	7.7	9.4	10.9	....	19.6
Mulch tillage	17.1	22.2	16.3	12.1	6.8	9.5	10.6	18.3	18.0

Emergence and plant development as affected by mulch tillage. There was no apparent difference in the time of emergence of the corn plants on mulch tilled and plowed soil, however, the number of plants that did emerge was 7 percent less than on the plowed soil. These stand differences were eliminated as a source of variation in the experiment by overplanting and thinning to a uniform stand.

Growth measurements in 1950 and 1951 (13, 16) showed that plants grown on plowed soil were slightly heavier than plants grown on mulch-tilled soil until late June. The height of plants and silking date appeared to be delayed about one day by mulch tillage. By early September there was no difference in the development of the plants under the two tillage conditions.

Weed growth on plowed and mulch-tilled soil. The mulch-tilled plots contained more weeds than the plowed plots and because of the soddy nature of the surface eradication by cultivation was more difficult. Elimination of these weeds by spraying with 2,4-D did not significantly increase the yield of corn. Volunteer grasses reported by some investigators to be a problem on mulch-tilled soil were virtually eliminated by the predisking of the sod.

TABLE 5.—Average Soil Temperature at 4-inch Depth in Mulched and Mulch-tilled Soil, 1955

Treatments	June	July	August
	°F.	°F.	°F.
Plowed and manure mulch	73	74	75
Plowed, manure under	73	74	71
Plowed and manure mulch	. .	74	71
Plowed and straw mulch	. .	74	71
Mulch tillage	71	73	71

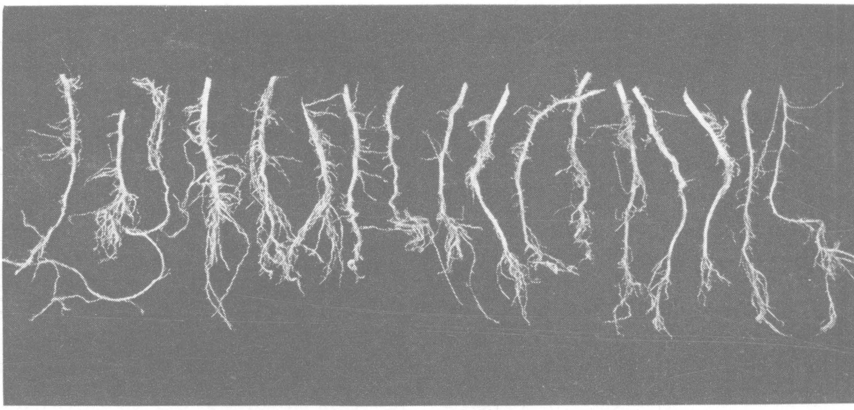

Fig. 3.—Corn roots from plowed soil

Root growth as affected by mulch tillage. A study of the root development of corn plants on the plowed and mulch-tilled plots made in 1949 and 1950 showed that corn plants on mulch-tilled soil had a greater proliferation of roots near the surface of the soil whereas those on plowed soil branches were more abundant at plow sole depth. (Fig. 3 and 4).

Potash content of corn plant tissue grown on plowed and mulch-tilled soil. In 1954 the potassium content of the corn leaves (Table 8) taken from plants on the mulch-tilled soil was significantly less than on plowed soil when both were fertilized in the conventional manner.

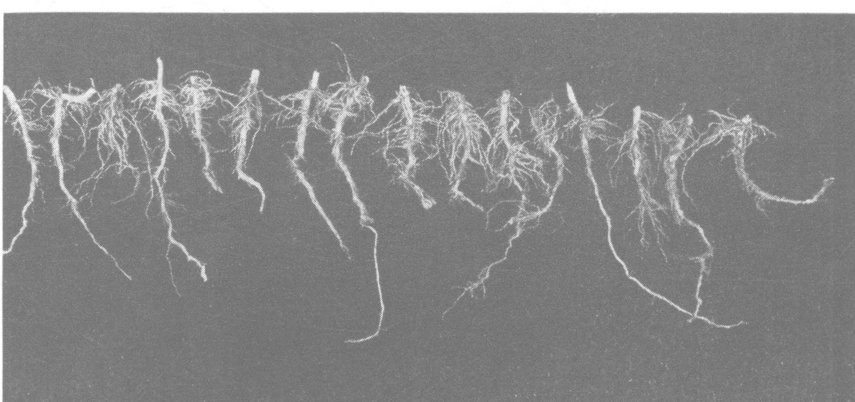

Fig. 4.—Corn roots from mulch-tilled soil

TABLE 6.—Bulk Density of Plowed and Mulch-tilled Soils

	August 1949			July 1950			July 1954		June 1955		3-year averages	
Depth	Plowed	tilled Mulch	Depth	Plowed	tilled Mulch	Depth	Plowed	tilled Mulch	Plowed	Mulch tilled	Plowed	Mulch tilled
In.	Pct.	Pct.	In.	Pct.	Pct.	In.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
0–2	1.25	1.23	1–4	1.27	1.30	0–2	1.21	1.24	1 32	1 22	1.26	1.23
2–4	1.27	1.32				2–4	1.18	1.26	1.41	1.44	1.28	1.34
4–7	1.23	1.32	4–7	1.27	1.36	4–6	1.16	1.25	1.39	1 50	1.26	1.36

TABLE 7.—Oxygen Percent by Volume, 1953

	1	2	3	Av.
Plowed	19.8	19.7	20.0	19.8
Plowed and straw mulch	19.5	19.3	19.5	19.4
Mulch tillage	18.9	19.5	19.3	19.2

Placing one-half of the fertilizer near the seed and the remainder 3 inches to the side of the seed and 5 inches deep increased the potassium content of the leaves of plants on mulch-tilled plots to the same level found in leaves of plants on plowed soil. In 1955 the potassium content of the leaves was not significantly affected by fertilizer placement.

Soil moisture content of plowed and mulch-tilled soils. The percentage soil moisture in manure and straw-mulched soil shown in Table 4 ranged from 1 to 9 percent higher than in non-mulched soil. Under mulch tilled conditions soil moisture was not as high as in the surface mulched plots but was consistently higher than in the nonmulched plowed soil.

Soil temperature. In 1950 and 1951 soil temperatures in the mulch-tilled plots averaged 2° to 3° lower than plowed plots throughout the growing season (13, 16). The soil temperature data for 1955 in Table 5 show that the soil temperature difference between the variously treated plots was of the order of 1 to 2° F. and not likely to be of consequence to growth.

STUDIES OF SOIL LOSS AND RUNOFF

The soil and water conserving value of manure mulches is shown in Table 3 and 4. As indicated in the Experimental Procedure section these data were secured from specially designed experiments and not from the corn yield experiment.

The five-year averages for July and August show that the unmulched soil lost 4.1 inches of water compared to 1.8 inches from the mulched plots. Erosion was reduced from 12.2 tons per acre to less than half a ton by the manure mulch. These differences show the effectiveness of mulches as a means of conserving both soil and water. In most years the losses were small because of the absence of high intensity rainfall.

TABLE 8.—Runoff and Erosion During July and August as Affected by Application of Manure Mulch

Year	Rainfall	Manure Plowed Under			Manure Mulch		
		Runoff	Effective* rainfall	Erosion	Runoff	Effective* rainfall	Erosion
	In.	In.	In.	T/A.	In.	In.	T/A.
1945†	10.75	3.5	7.2	40.7	1.5	9.3	1.31
1950‡	9.75	3.6	6.1	2.7	3.0	6.8	.13
1951	9.61	5.7	3.1	1.7	2.2	7.4	.04
1952	7.45	4.0	3.5	7.1	1.7	5.8	.44
1953	5.63	3.8	1.8	9.7	.6	5.0	.39
Av.	8.6	4.1	4.5	12.2	1.8	6.9	.46

*Total rainfall less runoff.

†Zanesville data, Muskingum silt loam, 12% slope.

‡Wooster data (1950-1953), Canfield silt loam, 10% slope

DISCUSSION

These studies show that an application of strawy manure or straw to corn land increased production, reduced erosion and increased water infiltration. The increases in yield from mulches applied after the corn had emerged can be attributed to greater water infiltration and a higher soil water content. Generally the differences in yield were greater in dry years when soil moisture was a limiting factor.

The high loss of soil where manure was plowed down occurred in a 4-year rotation of corn, wheat and meadow in which corn followed two years of alfalfa-timothy meadow. Over a long period of time the benefits of applied mulches would likely be greater than those obtained in the present investigation.

Mulch tillage, in which much of the existing stubble or sod remains on the surface and serves as a mulch, has been used extensively for a number of years, particularly in the semi-arid parts of the country to conserve soil and water. This practice is highly effective for controlling runoff and erosion but its practicability depends on how successfully corn may be grown with this system of seedbed preparation.

A common experience with mulch tillage in some states in the corn belt is that the practice has given somewhat lower yields than the conventional method of plowing. This study also shows that the yields of corn on the mulch-tilled soil were smaller than the yields produced on conventionally prepared soil. Under the conditions of the experiment the difference in yield was not statistically significant. The smaller yields on mulch-tilled soil in some years may not have been due to the kind of tillage but to the thoroughness with which the mulch tillage operation was performed. Unlike plowing which is a more or less complete method of soil preparation, mulch tillage may range from only a superficial loosening of the soil to a very thorough kind of tillage.

In much-tilled seedbeds either overtillage with a destruction of the desirable physical characteristics of the soil or undertillage may be responsible for reduced corn yields. It is the opinion of the writers that in 1949 the plots were over-worked and in 1953 and 1955 they were underworked. Mulch tillage is more of an art than conventional plowing. In the absence of a qualitative and quantitative definition of rootbed characteristics required for optimum corn-plant development, it is not possible to evaluate critically the physical character of the mulch-tilled plots and its relation to plant development. Although mulch tillage is preferable to plowing from the standpoint of erosion control, it did not produce as much corn as conventional plowing. It is probable that in compact soils plowing may be of value in loosening the soil. Very dense sods are not amenable to mulch tillage. The long term advantage of mulch tillage would be most apparent on steeply sloping areas where a decline in fertility with continued erosion is most severe.

This work indicates that a factor in the decreases in yield from mulch tillage may have been inadequate fertilization. Perhaps rate and placement of fertilizer should be different under mulch tillage than under conventional tillage.

The advantage of mulch tillage over applied mulches is that it utilizes the existing vegetation for mulch rather than having to apply a mulch after the corn is planted. On the other hand mulching with manure or straw has the advantage of controlling erosion as well as producing corn yields that are significantly larger than those produced on mulch tilled or conventionally plowed soil.

PRACTICAL CONSIDERATIONS

The practice of mulching corn is most applicable to strip-cropped land where serious cross-strip washing occurs and on fields where slopes are too irregular to permit contour culture.

Certain practical matters regarding the application of this practice should be pointed out. Surface mulching will necessitate having a supply of manure or crop residues on hand at the proper time. Manure mulching to be successful requires a heavier application than is customary on many farms. Obviously the quantity of residues or manure available will determine the extensiveness of the practice. The manure should be well supplied with bedding to be satisfactory to use for mulching. Old straw or spoiled hay may also be used if a forage harvester is available for spreading. The use of a manure spreader with high speed beater is necessary to insure thorough shredding and prevent damaging the corn with chunks of manure. To offset some damage to plants by the falling mulch, a somewhat heavier than ordianry rate of planting is recommended for areas to be surface mulched. Corn rows should be spaced 38 or 40 inches (but no closer) to accommodate the wheels of the spreader.

The mulch-tillage method of seedbed preparation used in the present studies is adapted to grass-legume sod that can be easily destroyed. The sod should be killed by early disking before the tilling implement is used. In extremely wet springs the mulch tillage practice may be a disadvantage since mulch-tilled soil does not dry as readily as plowed soil and planting may be delayed. Delayed planting was necessary in one of the preliminary years of the experiments. Preparing ground for corn with a field cultivator requires more judgment than plowing does. The soil should be loosened thoroughly to plow-depth. Usually twice over the field in one direction and once at right angle will do the job. The surface should be disked enough to provide a fairly firm seedbed. If large sod clumps remain on the surface it is desirable to provide some device on the planter runner to push the clumps aside.

Because of somewhat lower percentage emergence of seed on a mulch-tilled seedbed a higher rate of planting is advisable.

SUMMARY AND CONCLUSIONS

1. Significantly larger corn yields were produced on soil which received 10 tons of manure or 2 tons of wheat straw applied as a mulch when the corn was 10 to 15 inches high than when the same quantity of manure was plowed down. The increases from mulching were largest during years of low rainfall and appeared to be related to the higher soil-moisture content under mulched conditions.

2. During a seven year period corn grown on mulch-tilled soil averaged approximately 7 bushels less than corn grown on conventionally plowed soil, and approximately 9 bushels less than on plowed soil mulched with straw or manure. Under the conditions of this experiment the difference in yield produced by conventional plowing and mulch tillage were not statistically significant.

3. Although the cause of the difference in corn yield produced on mulch-tilled and conventionally-plowed seedbeds is not known, it may be related to the higher bulk density of the soil and reduced potassium absorption by the plant under mulch-tilled conditions.

4. In a two-year test, split fertilizer application with one-half of the fertilizer near the seed and the remainder 5 inches below seed level produced a corn yield on mulch-tilled soil equal to the yield produced on conventionally plowed soil.

5. In a separate experiment, the average loss of runoff water on 10 and 12 percent slopes was 4.1 inches on nonmulched soil and 1.8 inches on manure mulched soil. Erosion was reduced from 12.2 tons to 0.5 tons per acre by manure mulching.

6. The application of surface mulches to corn has the advantage of reducing erosion and runoff as well as increasing corn yields. On the other hand while the mulch-tillage type of seedbed preparation reduces runoff and erosion it has the disadvantage of producing somewhat lower yields than conventional plowing.

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